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Food Security and Marginal Productivity of Labor in Jordan

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Abstract

Objectives: The primary goal of this study is to explore the relationship in the Jordanian economy between the marginal productivity of labor and the level of food security. Additionally, the study estimates the production function in the Jordanian economy.

Methods: The estimation relied on the Cobb-Douglas production function using the Autoregressive Distributed Lag (ARDL) model. Subsequently, the marginal productivity of labor (MPL) was estimated by partially differentiating the production function with respect to labor. The marginal productivity of labor for each year from 2001 to 2019 was calculated based on the values of capital formation and labor compensation for each year.

Results: The estimation results indicated that the Jordanian economy is labor-intensive, with the elasticity of production for labor being approximately 0.64, compared to the elasticity of production for capital, which was about 0.38. Additionally, the results revealed that the error correction model (ECM) coefficient equals (-0.3678), suggesting that short-term deviations in the relationship are adjusted back to a long-term equilibrium path within approximately 2.72 years. Furthermore, the analysis showed that if the level of food security decreased to 87.3%, the marginal productivity of labor would drop to zero.

Conclusion: The study recommends the development of a comprehensive national food security strategy, along with reforms in the labor market that encourage investment in high-wage sectors and the qualification of national labor to work in these sectors. This would contribute to enhancing food security and the marginal productivity of labor.

Keywords: Food security; Jordan; cobb-Douglas production function; marginal productivity of labor
JEL: D24, E23, J24

الأمن الغذائي والإنتاجية الحدية للعمالة في الأردن

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ملخّص

هدف الدراسة: الهدف الرئيسي من هذه الدراسة هو استكشاف العلاقة في الاقتصاد الأردني بين الإنتاجية الحدية للعمالة، ومستوى الأمن الغذائي، كما تم تقدير دالة الإنتاج في الاقتصاد الأردني.

المنهجية: تم الاعتماد في التقدير على دالة كوب دوجلاس (Cobb-Douglas) باستخدام نموذج الانحدار الذاتي الموزع (ARDL). وبعد ذلك تم تقدير دالة الإنتاجية الحدية للعمالة (MPL) باشتقاق دالة الإنتاج جزئيًا بالنسبة إلى العمل، ومن ثم تم احتساب الإنتاجية الحدية للعمالة لكل عام خلال الفترة من (2001-2019) اعتمادًا على قيم التكوين الرأسمالي وتعويضات العمالة في كل عام.

النتائج: بينت نتائج التقدير أن الاقتصاد الأردني هو اقتصاد كثيف العمالة، وقد بلغت مرونة الإنتاج للعمالة حوالي 0.64، مقارنة بمرونة الإنتاج لرأس المال والتي بلغت حوالي 0.38. كما بينت نتائج التقدير أن معامل نموذج تصحيح الخطأ (ECM) يساوي (-0.3678)، مما يشير إلى أن الانحرافات في العلاقة قصيرة الأجل يتم تعديلها من خلال العودة إلى مسار التوازن طويل الأجل في غضون 2.72 سنة. علاوة على ذلك، فقد أظهرت نتائج التحليل أنه إذا انخفض مستوى الأمن الغذائي إلى 87.3٪، فإن الإنتاجية الحدية للعمالة ستنخفض إلى الصفر.

خلاصة الدراسة: توصي الدراسة بإعداد استراتيجية وطنية متكاملة للأمن الغذائي، بالإضافة إلى إجراء إصلاحات في سوق العمل تتضمن تشجيع الاستثمار في القطاعات ذات الأجور المرتفعة، وتأهيل العمالة الوطنية للعمل في هذه القطاعات بما يسهم في زيادة الأمن الغذائي والإنتاجية الحدية للعمالة.

الكلمات الدالة: الأمن الغذائي، الأردن، دالة إنتاج كوب-دوغلاس، الإنتاجية الحدية للعمل

Introduction

Food security plays a crucial role in the overall national security of any nation. It reflects the ways in which a country responds to social, economic, institutional, and technological challenges. It also involves a variety of interconnected issues, such as health, poverty, nutrition, hunger, resource depletion, climate change, and social and economic inequality.

Poverty, inequality, and undernourishment require governments to increase their spending on social safety nets and cash transfers.

Not only does food security carry considerable benefits to the health of humans, but it also one of the main pillars for achieving sustainable growth economically. It does so by raising productivity of labor, which is vital to promote and improve economic development and growth in a country.

Therefore, it is important to recognize that a food security strategy cannot be viewed as a solitary sector issue, but rather requires coordinated efforts across various sectors. These sectors may include agriculture, education, nutrition, health, infrastructure, finance, and others.

This study explores the effect of food security on the productivity of labor in Jordan.

The main hypothesis of this study is:

The food security level has a positive impact on the marginal productivity of labor in Jordan at significance level ($\alpha \leq 5\%$).

Literature Review

Several studies show that food security impacts labor productivity. For instance, Tiwasing et al. (2019) found positive significant effects of iron, vitamin A, and calcium intakes on labor productivity. Berha et al. (2021) also discovered that improving nutritional quality and food variety can increase farm labor productivity for households with poor diets.

Conversely, labor productivity influences food security. Okoye et al. (2016) found that higher labor productivity positively affects the food security of farmers, with younger farmers being more food secure than older ones due to their higher productivity.

Devesh and Affendi (2020) found that in Oman, population growth rate and GDP per capita positively affect food security. Hanif et al. (2019) studied 15 developing countries and found that macroeconomic and environmental factors significantly impact food security, including population, GDP, foreign direct investment, food aid, CO_2 emissions, and combustible renewable wastes.

Świetlik (2018) examined GDP and food security across regions and countries. They found that GDP per capita is closely linked to food security, with countries having higher GDP per capita being more food secure. Furthermore, an increase in GDP per capita corresponds to improved food security.

In summary, various studies highlight the interaction between food security, labor productivity, and other factors such as nutrition, population, GDP, and environmental considerations. And since food security and labor productivity have a mutual impact, this could lead to a trap of (food security-labor productivity).

Food Security in Jordan

According to a study by the Jordanian Department of Statistics (2016), 9.6% of families in Jordan received food aid, while 5.9% received non-food aid. The study also revealed that 80% of food-insecure families had an annual income below 5,000 Dinars, and 14% of insecure households received monetary or compensatory assistance from the National Aid Fund. Additionally, the study found a direct relationship between adaptation mechanisms and family size, and an inverse relationship between adaptation and the educational level of the family's main provider.

To mitigate the macroeconomic impact of COVID-19, Jordan has cooperated with the IMF to ensure that emergency health and economic needs don't disrupt its balance of payments. It is important to assess whether this assistance includes support for Jordan's food supply chain (WB et al., 2020).

Despite vulnerabilities, food security among Jordanian households has remained relatively stable. In 2020, 15% of households had poor or borderline Food Consumption Scores (FCS), compared to 16% in 2018 (WB et al., 2020).

According to the available data of the prevalence of undernourishment in Jordan, Table 1 shows the level of food security in Jordan during the period from (2001-2019):

Table 1: The level of food security in Jordan during the period (2001-2019)

Year	* PoU %	** FS%
2001	9.70	90.30
2002	7.70	92.30
2003	6.30	93.70
2004	5.70	94.30
2005	5.50	94.50
2006	5.70	94.30
2007	6.10	93.90
2008	6.50	93.50
2009	6.90	93.10
2010	7.10	92.90
2011	7.50	92.50
2012	8.50	91.50
2013	7.90	92.10
2014	7.20	92.80
2015	6.30	93.70
2016	7.10	92.90
2017	7.70	92.30
2018	8.20	91.80
2019	9.50	90.50

Source: *: https://www.fao.org/fileadmin/user_upload/faoweb/statistics/SDG/2.1.1_Prevalence_of_undernourishment____.xlsx, **: Calculated

Note: PoU: denotes for Prevalence of Undernourishment.

FS: denotes for the level of food security, where FS = 1-PoU

Figure 1 shows the level of food security in Jordan during the period between (2001-2019):

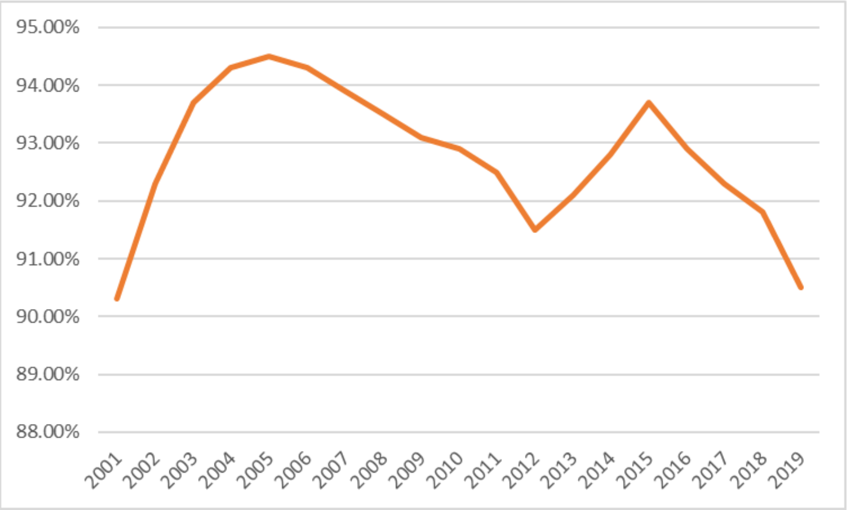

Figure 1: The level of food security in Jordan during the period (2001-2019)

Source: Output of Microsoft Excel Charts depending on Table 1

It can be noticed from the level of food security in Jordan increased from 90.3% to 94.5 between the period (2001 – 2005), then started to decrease until it reached to 91.50% in 2012, then it increased in the next three years until it reached to 93.7% in 2015, then started to decrease very quickly until it reached to 90.50% in 2019.

Labor Force and Labor Compensations in Jordan

Since the data of monthly compensation is not available, it is estimated according to the percentage of contribution in social security, and the percentage of other benefits which was calculated from the available data for the year of 1998 as below:

(In-kind gifts + Other Benefits) / Cash Payments

Which equals: ((21,277 + 58,748) / 1,282,038) = (6.24%)

Table 2: Average monthly compensation during the period (2000-2019)

Year	* Average monthly salary (JD)	Percentage of contribution in social security %	** Average monthly contribution in social security (JD)	** Other benefits %	** Average monthly benefits (JD)	** Average monthly compensation of employee (JD)
2000	226	12.25	27.71	6.24	14.12	268.1
2001	232	12.25	28.42	6.24	14.48	274.9
2002	240	12.25	29.39	6.24	14.98	284.3
2003	244	12.25	29.89	6.24	15.23	289.1
2004	242	12.25	29.62	6.24	15.09	286.5
2005	262	12.25	32.07	6.24	16.34	310.2
2006	280	12.25	34.24	6.24	17.45	331.2
2007	305	12.25	37.32	6.24	19.02	361.0
2008	351	12.25	42.95	6.24	21.88	415.4
2009	366	12.25	44.78	6.24	22.82	433.2
2010	392	12.25	47.98	6.24	24.45	464.1
2011	416	12.25	51.02	6.24	26.00	493.5
2012	437	12.25	53.55	6.24	27.29	518.0
2013	463	12.25	56.75	6.24	28.92	548.9
2014	463	14.25	65.97	6.24	28.90	557.8
2015	484	14.25	68.92	6.24	30.19	582.7
2016	493	14.25	70.20	6.24	30.75	593.5
2017	500	14.25	71.26	6.24	31.22	602.6
2018	524	14.25	74.74	6.24	32.74	632.0
2019	543	14.25	77.32	6.24	33.87	653.8

Source: *: http://www.dos.gov.jo/owa-user/owa/employment.em_select?lang=A&dist_t=5, **: Calculated

Table 3: Total real compensation of employees (1992-2019)

Year	* Average monthly compensations	*** Average yearly compensations (JD)	** Consumer price index (2016 = 100%)	*** Average real yearly compensations (JD)	** Labor force (Total number of workers)	*** Total real compensation of employees (JD)
1992	198.0	2,376.0	46.42	5,118.8	916,676	4,692,251,572
1993	210.0	2,520.0	47.96	5,254.7	997,893	5,243,643,072
1994	244.0	2,928.0	49.64	5,898.1	1,077,762	6,356,706,236
1995	245.0	2,940.0	50.81	5,786.1	1,151,270	6,661,340,227
1996	251.0	3,012.0	54.11	5,565.9	1,190,714	6,627,426,961
1997	269.0	3,228.0	55.76	5,789.2	1,222,451	7,077,022,505
1998	284.0	3,408.0	57.48	5,928.7	1,249,468	7,407,757,446
1999	285.0	3,420.0	57.83	5,913.8	1,274,562	7,537,444,236
2000	268.1	3,216.7	58.22	5,525.4	1,299,796	7,181,895,926

Year	* Average monthly compensations	*** Average yearly compensations (JD)	** Consumer price index (2016 = 100%)	*** Average real yearly compensations (JD)	** Labor force (Total number of workers)	*** Total real compensation of employees (JD)
2001	274.9	3,298.7	59.25	5,567.5	1,327,778	7,392,464,488
2002	284.3	3,411.4	60.33	5,654.2	1,346,874	7,615,450,244
2003	289.1	3,469.3	61.32	5,657.8	1,361,866	7,705,167,621
2004	286.5	3,438.2	63.38	5,424.8	1,404,997	7,621,870,947
2005	310.2	3,721.9	65.59	5,674.2	1,455,960	8,261,447,752
2006	331.2	3,974.6	69.69	5,702.9	1,507,627	8,597,817,177
2007	361.0	4,332.2	73.00	5,934.4	1,630,985	9,678,983,743
2008	415.4	4,984.9	83.20	5,991.5	1,702,117	10,198,211,187
2009	433.2	5,198.3	82.59	6,294.4	1,828,703	11,510,639,532
2010	464.1	5,569.6	86.59	6,432.4	1,897,304	12,204,134,672
2011	493.5	5,921.6	90.19	6,565.6	1,975,965	12,973,411,873
2012	518.0	6,215.6	94.26	6,593.8	2,049,550	13,514,404,625
2013	548.9	6,587.3	98.81	6,666.5	2,112,264	14,081,480,266
2014	557.8	6,694.1	101.68	6,583.8	2,224,664	14,646,695,759
2015	582.7	6,992.8	100.78	6,938.4	2,330,983	16,173,249,451
2016	**593.5**	**7,122.5**	**100.00**	**7,122.5**	**2,426,998**	**17,286,309,566**
2017	602.6	7,230.9	103.32	6,998.3	2,511,178	17,573,863,045
2018	632.0	7,583.4	107.93	7,025.9	2,585,020	18,162,210,778
2019	653.8	7,845.1	108.76	7,213.4	2,649,637	19,112,966,961

Source: *: http://www.dos.gov.jo/owa-user/owa/em_select_t1?lang=A&dis_t=70, and table 3.1,

: https://api.worldbank.org/v2/en/country/JOR?downloadformat=excel, *: Calculated

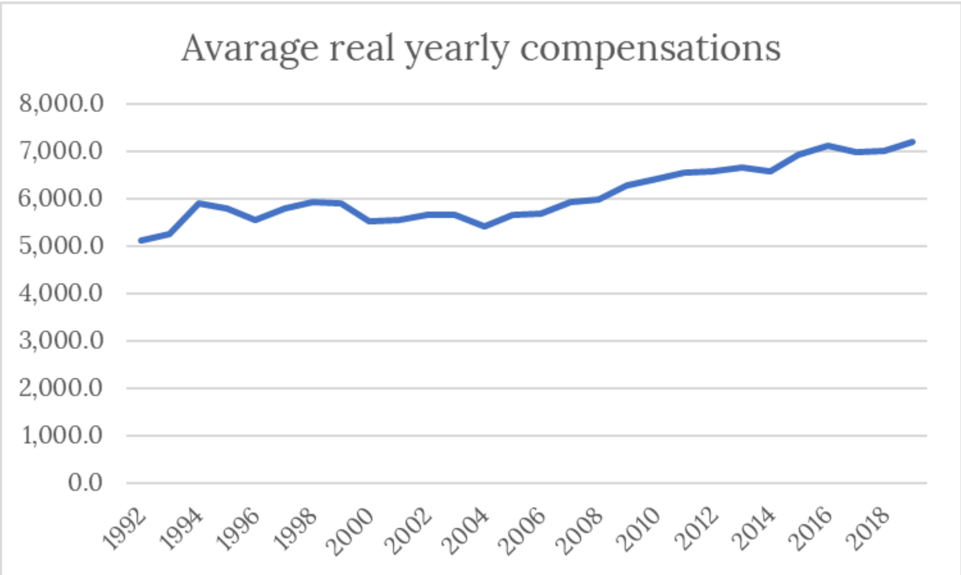

Figure 2: Average real yearly compensations

Source: Output of Microsoft Excel Charts depending on Table 3

It can be noticed from the above figure that average real yearly compensations was increased during the period (1992-2019).

The real GDP, Capital Formation, and Capital Stock

Since the capital stock data is not available for Jordan, it is estimated depending on the incremental capital-output ratio (ICOR) approach (Adelman and Chenery, 1966). This approach requires to at first to calculate the overall ICOR for the period of the study. The following equation is used to calculate the ICOR (Hammad, 1986):

$$ICOR_{(1992-2020)} = \frac{\sum_{t=1992}^{2020} K_t}{GDP_{2020} - GDP_{1992}}$$

Capital Stock value for the first year is calculated by multiplying the calculated ratio of ICOR by the value of Gross Domestic Product (GDP) of that year. Next values of Capital Stock are calculated by adding the Gross Capital Formation in each year to the value to Capital Stock of the previous year.

Table 4: The real GDP, Capital Formation, and Capital Stock (1992-2019)

Year	*** Real GDP (JD)**	*** Real Gross Capital Formation (JD)**	**** Real Capital Stock (JD)**
1992	9,697,396,200	2,664,675,000	56,641,323,949
1993	10,132,517,300	2,903,417,600	59,544,741,549
1994	10,636,253,100	2,777,354,000	62,322,095,549
1995	11,295,793,800	2,896,591,300	65,218,686,849
1996	11,531,539,300	2,524,372,700	67,743,059,549
1997	11,913,057,500	2,201,687,700	69,944,747,249
1998	12,271,899,300	1,999,991,100	71,944,738,349
1999	12,687,859,100	2,016,394,500	73,961,132,849
2000	13,226,549,100	2,165,507,800	76,126,640,649
2001	13,923,582,600	2,154,040,300	78,280,680,949
2002	14,728,895,900	2,209,992,200	80,490,673,149
2003	15,341,863,500	2,468,743,000	82,959,416,149
2004	16,656,233,900	3,609,216,200	86,568,632,349
2005	18,013,149,800	4,926,246,800	91,494,879,149
2006	19,470,949,500	4,677,201,700	96,172,080,849
2007	21,062,927,500	5,127,745,800	101,299,826,649
2008	22,586,265,600	6,446,284,100	107,746,110,749
2009	23,720,934,100	6,672,144,700	114,418,255,449
2010	24,270,034,400	7,218,342,600	121,636,598,049
2011	24,934,348,900	6,832,906,200	128,469,504,249
2012	25,540,093,500	5,995,285,800	134,464,790,049
2013	26,206,676,500	5,706,392,900	140,171,182,949
2014	27,093,530,900	5,938,009,300	146,109,192,249
2015	27,769,928,700	6,010,780,400	152,119,972,649
2016	**28,323,711,300**	**5,676,000,000**	**157,795,972,649**
2017	28,914,859,600	6,212,906,500	164,008,879,149
2018	29,474,099,500	5,138,203,800	169,147,082,949
2019	30,050,455,600	3,709,336,100	172,856,419,049
	$GDP_{2020} - GDP_{1992} =$ 20,353,059,400	$\sum_{t=1992}^{2020} K_t =$ 118,879,770,100	
	ICOR =	5.841	

Source: *: https://api.worldbank.org/v2/en/country/JOR?downloadformat=excel, **: Calculated

Figure 3 shows the Real GDP and the Real Capital Stock during the period (1992-2019).

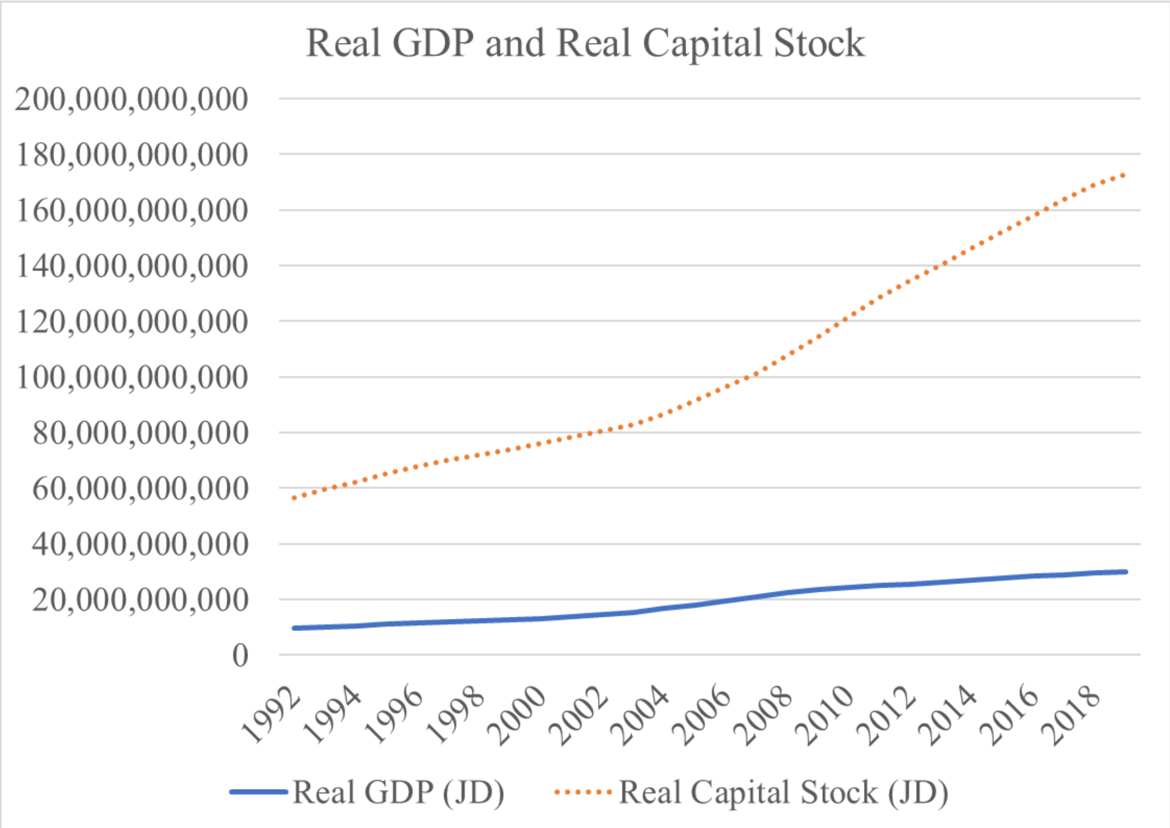

Figure 3: Real GDP and Real Capital Stock

Source: Output of Microsoft Excel Charts depending on Table 4

It can be noticed from the above figure that Capital Stock was increasing faster than GDP during the period (1992-2019) which is an indicator that the amount or quality of labor is not aligned with the capital stock, where the productivity of labor needs improvement. Also, this is an indicator that the level of technology needs improvement.

Econometric Model

The Cobb-Douglas production function, introduced by Douglas and Cobb (1928), relates inputs of labor and capital to output in the manufacturing industry, and it takes the following form:

$$Y_t = A\, K_t^{\alpha_1} L_t^{\alpha_2} e^{\varepsilon_t} \qquad (1)$$

Where $\mathbf{Y_t}$ represents the output level (GDP), $\mathbf{K_t}$ represents capital, and $\mathbf{L_t}$ represents labor.

A represents the other factors that effect on the output. These factors could include the technology level.

Taking the natural logarithm of both sides gives the below equation:

$$ln(Y_t) = ln\, A + \alpha_1 ln\,(L_t) + \alpha_2 ln\,(K_t) + \varepsilon_t \qquad (2)$$

Where ε_t is the random error term.

If $ln\, A = \alpha_0$, then the model will be:

$$ln(Y_t) = \alpha_0 + \alpha_1 ln\,(L_t) + \alpha_2 ln\,(K_t) + \varepsilon_t \qquad (3)$$

After estimating the production model variables, then taking the partial derivative of Y with respect to L, which gives the Marginal Productivity of Labor function:

$$MPL_t = \frac{\partial Y}{\partial L} = g(K_t, L_t) \quad (4)$$

Then estimating the MPL_t for each year depending on the values of K_t, L_t for that year. After that, the MPL_t will be considered as a function of food security:

$$MPL_t = h(FS_t) \quad (5)$$

Where FS_t is Food Security percentage, and it will be calculated depending on the Prevalence of Undernourishment (**PoU**) where: **FS = 1 - PoU**.

Descriptive statistics of the study variables

Table 5 shows the Descriptive statistics for Production Function variables. The following can be concluded:

- The Jarque-Bera probability value is above 5%, which means that all variables have a normal distribution.
- Skewness is a little bit positively skewed out for all variables.
- Kurtosis less than 3 for all variables which means that these variables have a platykurtic distribution.

Table 5: Descriptive statistics for Production Function variables

	Y_t	K_t	L_t
Mean	19,338,407,357	4,245,706,075	10,467,723,853
Median	18,742,049,650	4,193,268,900	8,429,632,465
Maximum	30,050,455,600	7,218,342,600	1,911,296,6961
Minimum	9,697,396,200	1,999,991,100	4,692,251,572
Std. Dev.	7,035,295,874	1,802,285,432	4,316,570,006
Skewness	0.1043	0.1226	0.6447
Kurtosis	1.4588	1.4291	2.0766
Jarque-Bera	2.8218	2.949	2.9347
Probability	0.2439	0.2289	0.2305
Sum	541,475,406,000	118,879,770,100	293,096,267,870
Sum Sq. Dev.	1.336375477e+21	8.7702284972e+19	5.03084968694e+20
Observations	28	28	28

Prediagnostic Tests

Unit Root Test for Stationarity

The unit root test is used to determine the order of integration of the time series under consideration by testing a series of regressions of original values. It tests if the series is stationary or not, then checks the stationary of its first difference, then tests the stationary of its second difference. The null hypothesis of the unit root test is that the series is non-stationary. 90

The unit root test for stationarity used in this study is:

Dickey-Fuller Generalized Least Squares (DF-GLS)

Traditionally, testing unit root for a time series is done using (augmented) Dickey-Fuller and Phillips-Perron tests, but Elliott R., et.al (1996) suggested more effective test with better statistical properties available. This test modified the Dickey-Fuller test statistic using a generalized least squares (GLS) rationale.

They showed that this test has the best overall performance when the sample size is small, outperforming the ordinary Dickey-Fuller test. In particular, it has been found that the "DF-GLS" test has significantly improved power when an unknown mean or trend is present.

Table 6 shows the results of the unit root test with intercept for all variables. According to these results the null hypothesis of unit root test of the three variables for the levels is accepted at 10% of significance. The results of the test show that all of the three variables have a unit root at level. After testing the first differences, the results shows that all series are stationary. Hence, the ARDL model can be applied in this case if there is a cointegration among the variables.

Table 6: DF-GLS test for Production Function variables

Variable	DF-GLS	
	T-Calculated	**10% level**
***ln(Y_t)*:**		
Level	-0.6600	-1.6093
First difference	-1.7048*	-1.6093
Order of integration	I(1)	
***ln(K_t)*:**		
Level	-1.5791	-1.6088
First difference	-2.4424*	-1.6093
Order of integration	I(1)	
***ln(L_t)*:**		
Level	0.1559	-1.6082
First difference	-1.8118*	-1.6078
Order of integration	I(1)	

Note: * denotes the rejection of unit root hypothesis at 10% level

Lag Length Selection

To eliminate the effect of serial correlation of residuals, it is necessary to find the optimal number of lags for the variables in the model. Many criterions are used such as Akaike Info Criterion (AIC), Schwarz Criterion (SC), Hannan – Quinn (HQ), Final Prediction Error criterion (FBE), and Likelihood ratio test (LR), to find the optimal number of lags in the model.

Table 7 shows the lag length selection criteria:

Table 7: Lag Length Selection Criteria for variables: ln(Yt), ln(Kt), ln(Lt)

Lag Length Selection Criteria
Sample: 1992 2019
Included observations: 23
Endogenous variables: ***ln(Y_t)***, ***ln(K_t)***, ***ln(L_t)***
Exogenous variables: C

Lag	LogL	LR	FPE	AIC	SC	HQ
0	22.7254	NA	3.61E-05	-1.7152	-1.5671	-1.6780
1	143.8767	200.1631*	2.12E-09	-11.4675	-10.8751*	-11.3185
2	153.7535	13.7416	2.07E-09	-11.5438	-10.5070	-11.2830
3	160.4828	7.6071	2.86E-09	-11.3463	-9.8653	-10.9738
4	176.5810	13.9984	2.01E-09*	-11.9636	-10.0382	-11.4793
5	190.4556	8.4455	2.23E-09	-12.3875*	-10.0177	-11.7915*

* Indicates lag length selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Residual Serial Correlation LM test

Since 2 criterions selected (lag 1), and 2 criterions selected (lag 5) as shown in Table 7, there should be no serial correlation at the selected lag.

The results of Residual Serial Correlation LM Test as shown in Table 8 reveal that there is serial correlation at (lag 1), and as 2 criterions selected (lag 5) which is without serial correlation, then, the selected lag is (lag 5).

Table 8: Residual Serial Correlation LM Test for Endogenous variables: ln(Yt), ln(Kt), ln(Lt)

Null hypothesis: No serial correlation at lag h							
Lag	**LRE* stat**	**df**	**Prob.**	**Rao F-stat**	**df**	**Prob.**	**Result**
1	17.3856	9	0.0430	2.2262	(9, 34.2)	0.0444	There is serial correlation
2	11.3815	9	0.2505	1.3392	(9, 34.2)	0.2538	
3	7.1496	9	0.6215	0.7935	(9, 34.2)	0.6243	
4	8.4635	9	0.4882	0.9564	(9, 34.2)	0.4915	
5	5.9575	9	0.7442	0.6505	(9, 34.2)	0.7462	No serial correlation
Null hypothesis: No serial correlation at lags 1 to h							
Lag	**LRE* stat**	**df**	**Prob.**	**Rao F-stat**	**df**	**Prob.**	**Result**
1	17.3856	9	0.0430	2.2262	(9, 34.2)	0.0444	There is serial correlation
2	31.1369	18	0.0278	2.0983	(18, 31.6)	0.0332	There is serial correlation
3	35.1557	27	0.1350	1.4400	(27, 24.0)	0.1849	
4	56.0871	36	0.0176	1.9878	(36, 15.5)	0.0741	
5	70.2500	45	0.0094	1.6509	(45, 6.7)	0.2582	No serial correlation
*Edgeworth expansion corrected likelihood ratio statistic.							

Bound Test

The purpose of this test is to determine whether there is a long-term link between the variables regardless of whether the regressors are purely I(0), purely I(1), or mixed, using unrestricted error correction model (UECM) (Pesaran et al., 2001).

Then comparing the (F-statistic) with the following critical bounds:

- Lower Critical Bounds (LCB) which assume that the variables are integrated of order zero; I(0).
- Upper Critical Bounds (UCB) which assume that the variables are integrated of order one; I(1).

Since the calculated F-statistic values as shown in Table 9 are above UCB at a significance level of 10%, the results indicate that the null hypothesis of no cointegration in two cases are rejected. This implies that there are long-run cointegration relationships among the variables when the regressors are normalized.

Table 9: Bound Test Results for Variables: ln(Yt), ln(Kt), ln(Lt)

Equation	**F-Statistics**	**1%**		**5%**		**10%**		**K= 4**
		I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**The Decision**
		LCB	**UCB**	**LCB**	**UCB**	**LCB**	**UCB**	
$ln(\boldsymbol{Y}_t) = f(ln(\boldsymbol{K}_t), ln(\boldsymbol{L}_t))$	4.2231	4.13	5	3.1	3.87	2.63	3.35	Co-integration
$ln(\boldsymbol{K}_t) = f(ln(\boldsymbol{Y}_t), ln(\boldsymbol{L}_t))$	3.0989	4.13	5	3.1	3.87	2.63	3.35	No Co-integration
$ln(\boldsymbol{L}_t) = f(ln(\boldsymbol{Y}_t), ln(\boldsymbol{K}_t))$	3.6014	4.13	5	3.1	3.87	2.63	3.35	Co-integration

Estimating Production Function for the Jordanian Economy

Since the variables are I(1) and cointegrated, the estimation of the ARDL long-run can be performed.

Estimation of the long-run function takes the following form (Pesaran et al., 2001):

$$Y_t = \alpha + \sum_{i=1}^{P} \beta Y_{t-i} + \sum_{j=0}^{q} \gamma_j X_{t-j} + \varepsilon_t \quad (7)$$

Where:

$\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}$: parameters, $\boldsymbol{p}$ and $\boldsymbol{q}$: lagged values and $\boldsymbol{\varepsilon}_t$: random error term.

Why use ARDL?

In small or finite sample size, the Autoregressive Distributed Lag (ARDL) model is more effective (Fosu & Magnus, 2006). Additionally, it permits the variables to have various lags and does not mandate that the variables be integrated in the same order. The ARDL model is useful for both generating objective estimations of the long-run model and for addressing problems that result from nonstationary time series data. Additionally, it can fix endogeneity issues that caused the Engle-Granger approach to fail to test hypotheses by dividing the predictors' effects into long-run and short-run effects (Harris & Sollis, 2003).

Table 10 shows the long-run coefficients estimation.

Table 10: Estimation of long-run coefficients for Cobb-Douglas production function - ARDL with intercept

Method: ARDL		Selected model: ARDL(4,5,5)	
Dependent Variable: $ln(Y_t)$			
Automatic-lag linear regressors (5 max. lags): $ln(K_t)$ $ln(L_t)$			
Deterministics: Restricted constant and no trend (Case 2)			
Model selection method: Akaike info criterion (AIC)			
Regressors	**Coefficient**	**Standard Error**	**T-Ratio [Probability]**
ln(Kt)	0.3804	0.0646	5.89 [0.00]
ln(Lt)	0.6385	0.0733	8.71 [0.00]
Intercept	0.7027	1.1043	0.64 [0.53]
R^2: 0.9998		**Adjusted R^2**: 0.9992	
F-Statistic [probability]: 1623.8126 [1.48E-09]		**S. E. of Regression:** 0.0093	

The production function can be written as follows:

$$Y_t = 2.02\, K_t^{0.3804} L_t^{0.6385} \quad (8)$$

The estimated coefficients for Labor and Capital in the long-run relationship are highly significant (p<0.01) and align with economic theory. Labor and capital positively impact production, with labor elasticity at 0.64 and capital elasticity at 0.38. The Jordanian economy exhibits a return to scale close to 1, indicating almost constant returns and homogeneous GDP.

Also, the results show that the other factors like technology had a positive impact on the GDP in the Jordanian economy.

These results are very close to the results of Bakeer & Rfoa (2020). They found in their study to estimate the production function for six sectors representing the entire Jordanian Private economy during the period (2000- 2015) that the production function was $Y_t = 2.53\, K_t^{0.49} L_t^{0.58}$. While Said Hallaq (1995) found in his study on the Jordanian economy during the period between (1970-1990) that the production function was $Y_t = 0.5826\, K_t^{0.5153} L_t^{0.5192}$.

The error correction model ECM(-1) measures the speed of adjustment to equilibrium in the long run.

The short-run dynamics can be derived by building an error correction term (ECT) which takes the following form (Pesaran et al., 2001):

$$\Delta Y_t = \mu + \sum_{i=1}^{r} \alpha_i \Delta Y_{t-i} + \sum_{j=0}^{s} \delta_j \, \Delta X_{t-j} + \beta \, ECT_{t-1} + \varepsilon_t \qquad (9)$$

Where ECT is the error correction term, defined as:

$$ECT_t = Y_t - \alpha_1 - \sum_{i=1}^{P} \beta_i \, Y_{t-i} - \sum_{j=0}^{q} \delta_j \, X_{t-j} \qquad (10)$$

All of the short-run equation's coefficients relate the model's short-run dynamics of convergence to equilibrium, and $\boldsymbol{\beta}$ represents the speed of adjustment.

Table 11 reveals a negative speed of adjustment (-0.3678), strengthening the long-run equilibrium relationship's validity. The presence of error correction mechanism suggests a relatively high speed of 36.78% adjustment to equilibrium. The coefficient significance (less than 1%) confirms cointegration between independent and dependent variables.

Table 11: Estimation of Short-Run Coefficients for Cobb-Douglas Production Function - ARDL with Intercept

Method: ARDL		**Selected model: ARDL(4,5,5)**	
Dependent Variable: D($ln(Y_t)$)			
Automatic-lag linear regressors (5 max. lags): $ln(K_t)$ $ln(L_t)$			
Deterministics: No constant and no trend (Case 1)			
Model selection method: Akaike info criterion (AIC)			
Regressors	**Coefficient**	**Standard Error**	**T-Ratio [Probability]**
COINTEQ*	-0.3678	0.0730	-5.03 [0.0007]
D(ln(Kt))	0.0826	0.0237	3.49 [0.0069]
D(ln(Lt))	-0.1276	0.0652	-1.96 [0.0821]
R^2: 0.9504		**Adjusted R^2**: 0.8788	
F-Statistic [probability]: 13.2721 [0.0003]		**S. E. of Regression:** 0.0076	

This result is very close to the results of Bakeer & Rfoa (2020). They found in their study that the speed of adjustment equals (-0.3931).

Post-Diagnostic tests

Serial Correlation, and Heteroscedasticity tests

The model passes the tests for serial correlation and heteroscedasticity, as shown in Table 12. The table shows that there is no serial correlation exists, because the probability of all tests is higher than the 10% significance level so the null hypotheses are accepted, which means there is no serial correlation at up to 5 lags, and there is no heteroscedasticity.

Table 12: Serial Correlation Test, and Heteroscedasticity Test for production function

Equation	**Test**	**Test- Statistics**	**Prob.**
$ln(\boldsymbol{Y}_t) = f(ln(\boldsymbol{K}_t), ln(\boldsymbol{L}_t))$	**Serial Correlation test**	F -statistics = 5.7765	Prob. F(5, 1) = 0.3054
	Null hypothesis: No serial correlation at up to 5 lags		
	Heteroscedasticity test	F -statistics = 0.2796	Prob. F(16, 6) = 0.9807
	Null hypothesis: Homoskedasticity		

Stability Tests

The common stability tests, CUSUM and CUSUM Squares, assess whether residuals fall within the range of plus-orminus two standard errors. Stable parameters are indicated when residuals remain within this range, allowing acceptance of the null hypothesis of constant parameters without dividing the study period.

Figure 4 shows the CUSUM for production function, and Figure 5 shows the CUSUM Squares for the production function.

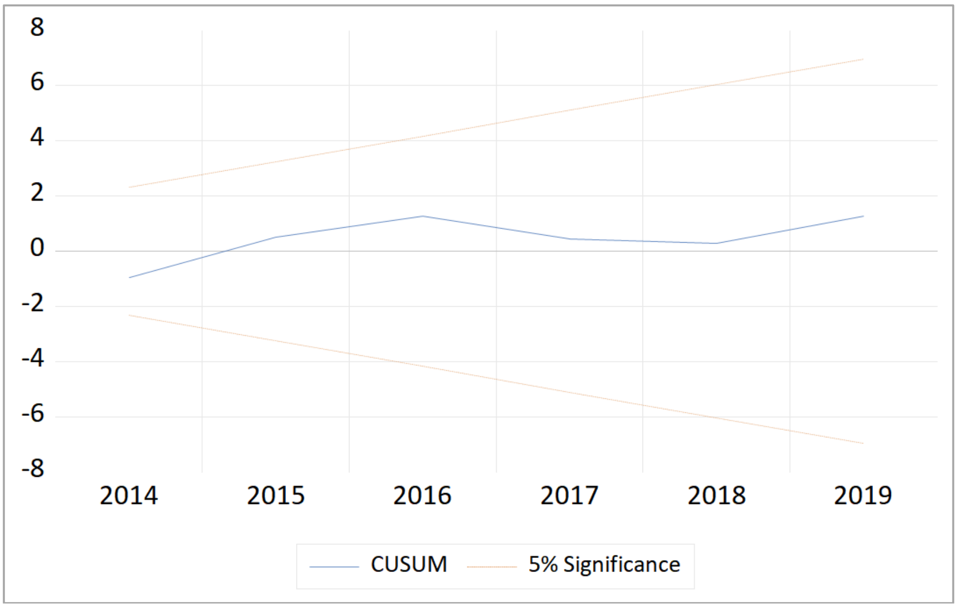

Figure 4: CUSUM for production function

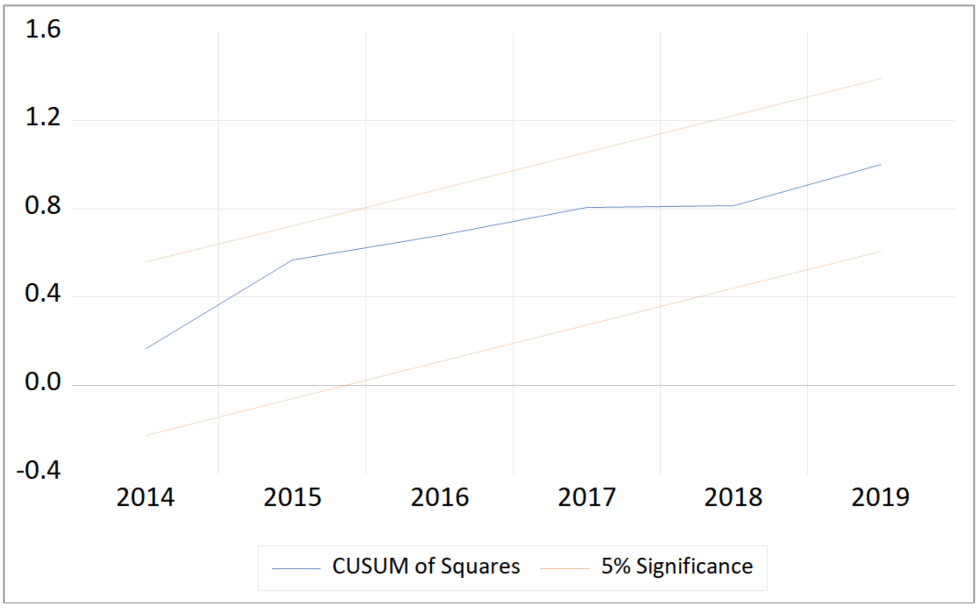

Figure 5: CUSUM of Squares for production function

As shown in figure 4, and in figure 5. At a 5% level of significance, the variables are clearly highly stable. Inferring that the estimation results for the entire study period (1992–2019) are adequate, there is no need to divide the study period into sub-periods.

Investigating the Impact of Food Security Level on the Marginal Productivity of Labor

According to the estimated production function which is:

$$Y_t = 2.02\, K_t^{0.3804} L_t^{0.6385}$$

The MPL_t is the partial derivative of Y_t with respect to L_t:

$$MPL_t = \frac{\partial Y_t}{\partial L_t} = 1.289\, K_t^{0.3804} L_t^{-0.3615} \quad (11)$$

According to equation (11), MPL_t for each year is as below:

Table 13: MPL_t Values

Year	* MPL_t	** FS_t%
2001	1.2406	90.30
2002	1.2394	92.30
2003	1.2872	93.70
2004	1.4932	94.30
2005	1.6325	94.50
2006	1.5777	94.30
2007	1.5654	93.90
2008	1.6758	93.50
2009	1.6252	93.10
2010	1.6395	92.90
2011	1.5706	92.50
2012	1.4724	91.50
2013	1.4237	92.10
2014	1.4250	92.80
2015	1.3812	93.70
2016	1.3193	92.90
2017	1.3574	92.30
2018	1.2478	91.80
2019	1.0822	90.50

Source: * Calculated, ** Table 8

Unit Root Test for Stationarity

Table 14 lists the outcomes of the unit root test with intercept for the two series. Therefore, according to the DF-GLS test, the unit root test null hypothesis for the values of the two variables is not rejected at the 10% significance level. The test's findings indicate that all of the variables have a unit root, however the first difference for both MPL and FS are stationary I(1).

Table 14: DF-GLS unit root test for MPL_t and FS_t

Null Hypothesis: *MPL_t* has a unit root **Exogenous:** Constant **Lag Length:** 0		
MPL_t	**DF-GLS**	
	T-Calculated	**10% level**
Level	-0.6036	-1.6066
First difference	-2.3387*	-1.6061
Order of integration	I(1)	
Null Hypothesis: *FS_t* has a unit root **Exogenous:** Constant **Lag Length:** 0		
FS_t	**DF-GLS**	
	T-Calculated	**10% level**
Level	-1.4958	-1.6066
First difference	-2.0076*	-1.6061
Order of integration	I(1)	

Note: * denotes the rejection of unit root hypothesis at 10% level

Johansen cointegration test

Johansen (1991) developed an MLE-based test for cointegration. Johansen (1995) identified two primary cointegration tests: the Trace Test and the Maximal Eigenvalue Test.

The results in Table 15 show that the cointegration exists for (lag 4) in the first differences at 0.05 of significance level, which means that there is a relationship in the long run between the variables.

Table 15: Johansen Cointegration Test for Endogenous variables: MPL_t , FS_t

Lags interval (in first differences): 1 to 4 Endogenous variables: ***MPL_t* , *FS_t*** Deterministic assumptions: Case 3 (Johansen-Hendry-Juselius): Cointegrating relationship includes a constant. Short-run dynamics include a constant. Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Trace Statistic**	**0.05 Critical Value**	**Prob.** Critical Value**
None *	0.7744	32.4694	15.4947	6.6E-05
At most 1 *	0.5640	11.6228	3.8415	0.0007
Trace test indicates 2 cointegrating equation(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values Unrestricted Cointegration Rank Test (Max-eigenvalue)				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.** Critical Value**
None *	0.7744	20.8466	14.2646	3.96E-03
At most 1 *	0.5640	11.6228	3.8415	0.0007
Max-eigenvalue test indicates 2 cointegrating equation(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

The Stock Watson dynamic OLS (DOLS) Model

Stock & Watson (1993) introduced the dynamic OLS model as a robust estimator for cointegrated series with small sample sizes. This model employs a GLS approach to address regressor endogeneity by incorporating serially correlated errors and including leads and lags for the first differences of the regressors. Table 16 shows the results of dynamic OLS estimation.

Table 16: Dynamic OLS for MPL_t, and FS_t

Method: Dynamic Least Squares (DOLS) Dependent Variable: MPL_t Fixed leads and lags specification (lead=0, lag=4)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
FS_t	25.6411	3.6676	6.9912	0.0002
C	-22.3720	3.4105	-6.5598	0.0003
R^2	0.8913	Long-run variance		0.0060
Adjusted R^2	0.7982	S.E. of regression		0.0758
S.D. dependent var	0.1687	Sum squared residuals		0.0402
Mean dependent var	1.4545			

The estimated function can be written as follows:

$$MPL_t = -22.37 + 25.64\, FS_t \tag{12}$$

The estimation results show that the food security level FS_t directly and positively affects the marginal productivity of labor MPL_t. The R^2 value is 0.8913, and this is due to the small sample size, and also this indicates that there are other factors influencing MPL_t. The negative intercept reflects the need for a negative correction in the expected values of MPL_t due to the small sample size. Equation 12 indicates that a 1-unit increase in food security leads to a and increase in MPL_t by 25.64 units. This generally aligns with the studies of Tiwasing et al. (2019) and Berha et al. (2021), albeit their focus was on labor productivity rather than marginal productivity.

Figure 5 shows the changes in the marginal productivity of labor and the food security level during the period between (2001-2019):

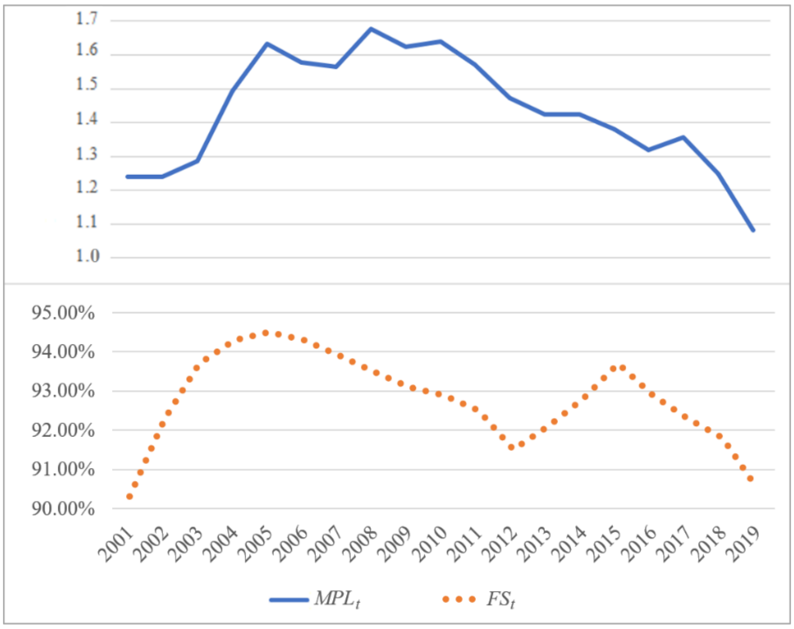

Figure 5: MPL$_t$ and FS$_t$

Source: Output of Microsoft Excel Charts depending on Table 13

It can be noticed from the above figure that when the level of food security FS_t increases, the marginal productivity of labor MPL_t tends to increase, and when the level of food security FS_t decreases, the marginal productivity of labor MPL_t tends to decrease, and these results are in line with the findings of equation 12 that shows there is a positive impact of the food security level on the marginal productivity of labor.

Residual Serial Correlation LM test

The results of Residual Serial Correlation LM Test shown in Table 17 reveal that no serial correlation at any lag.

Table 17: Residual Serial Correlation LM Test for Endogenous variables: MPL$_t$, FS$_t$

Null hypothesis: No serial correlation at lag h							
Lag	**LRE* stat**	**df**	**Prob.**	**Rao F-stat**	**df**	**Prob.**	**Result**
1	0.7911	4	0.9396	0.1913	(4, 18.0)	0.9398	No serial correlation
2	2.1944	4	0.7001	0.5509	(4, 18.0)	0.7008	No serial correlation
3	2.4641	4	0.6511	0.6231	(4, 18.0)	0.6519	No serial correlation
4	1.8233	4	0.7682	0.4532	(4, 18.0)	0.7688	No serial correlation
Null hypothesis: No serial correlation at lags 1 to h							
Lag	**LRE* stat**	**df**	**Prob.**	**Rao F-stat**	**df**	**Prob.**	**Result**
1	0.7911	4	0.9396	0.1913	(4, 18.0)	0.9398	No serial correlation
2	6.3853	8	0.6042	0.7978	(8, 14.0)	0.6143	No serial correlation
3	10.4090	12	0.5801	0.8346	(12, 10.0)	0.6221	No serial correlation
4	13.1227	16	0.6638	0.6540	(16, 6.0)	0.7684	No serial correlation
*Edgeworth expansion corrected likelihood ratio statistic.							

Conclusion

The analysis indicates that food security has a direct positive impact on the Marginal Productivity of Labor (MPL), with a 1-unit increase in food security raising MPL by 25.64 units. Labor's production elasticity is 0.64, higher than capital's

0.38, highlighting labor market imperfections that require structural reforms. To address this, the study recommends investing in industries that offer skilled, well-paid jobs and increasing government investment in labor force development. This approach will reduce unemployment, raise wages, and further improve food security, leading to higher MPL. The error correction model suggests that short-term deviations from equilibrium are corrected within 2.72 years.

Given food insecurity's impact on human capital development and sustainable growth, the study calls for a comprehensive national food security strategy. This strategy should involve coordinated efforts across all sectors like agriculture, education, health, and finance, alongside measures to support vulnerable groups and promote social justice.

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